Mission Requirements Flowdown

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GLAST Requirements Development Process

- **GLAST science requirements developed and sanctioned by NASA and DOE committees over past ~ 5 years**
- **Foundation**
  - EGRET science 1991 - 2000
  - SR&T/ATD/DOE GLAST development programs 1994 - 1999
- **Committees / Working Groups**
  - NASA Gamma Ray Astronomy Program Working Group (GRAPWG) 1997 - 1999
  - NASA SEU Subcommittee 1997 - 2000
  - DOE Scientific Assessment Group for Experiments on Non-Accelerator Physics (SAGENAP) 1998 - 1999
  - GLAST Facility Science Team 1998 - 1999
  - NAS Decadal Review of Astronomy & Astrophysics 1999 - 2000
  - GLAST Science Working Group 2000 -

NRC Decadal Review

Astronomy and Astrophysics in the New Millennium

Table 1.1 Prioritized Initiatives and Estimated Federal Costs for the Decade 2000-2010.

Ground Based	Cost ($M)	Space Based	Cost ($M)
Major Initiatives			
Giant Segmented-Mirror Telescope (GSMT)	350	Next Generation Space Telescope (NGST)	1000
Expanded Very Large Array (EVAL)	140	Constellation-X Observatory	800
Large-aperture Synoptic Survey Telescope (LSST)	170	Terrestrial Planet Finder (TPF)	200
		Single-Aperture Far Infra Red (SAFIR) Observatory	100
Moderate Initiatives			
Telescope System Instrumentation Program (TSIP)	50	Gamma-ray Large Area Space Telescope (GLAST)	300
Advanced Solar Telescope(AST)	60	Laser Interferometer Space Antenna (LISA)	250
Square Kilometer Array (SKA) Technology Development	22	Solar Dynamics Observatory (SDO)	300
Combined Array for Research in Millimeter-wave Astronomy (CARMA)	11	Energetic X-ray Imaging Survey Telescope (EXIST)	150
Very Energetic Radiation Imaging Telescope Array System (VERITAS)	35	Advanced Radio Interferometry between Space and Earth (ARISE)	350
Frequency Agile Solar Radiotelescope (FASR)	26		
South Pole Submillimeter-wave Telescope (SPST)	50		

Facility Science Team (FST)

- **Formed by NASA in 1997 to develop GLAST science and generate GLAST AO SRD**
- **Members chosen from astrophysics and particle physics communities. Technology development team members, community data experts, and theoreticians included.**
- **Final report was SRD. Signed off at NASA in January 2000. FST disbanded in June 1999.**
- **FST:**

Bill Atwood (SLAC)
Guido Barbiellini (Tresté)
Elliot Bloom (SLAC)
Alan Bunner (NASA HQ) Ex-Officio
Patricia Caraveo (CNR)
Lynn Cominsky (Sonoma State)
Brenda Dingus (Utah)
Jerry Fishman (MSFC)
Neil Gehrels (GSFC) Co-Chair
Isabelle Grenier (Saclay)
Alice Harding (GSFC)
Dieter Hartmann (Clemson)
Neil Johnson (NRL)
Robert Johnson (UCSC)
Tsuneyoshi Kamae (Tokyo)
Marc Kamionkowski (Columbia)
Don Kniffen (Hampden-Sydney College)
Scott Lambros (GSFC) Ex-Officio
Hans Mayer-Hasselwander (MPE)
Peter Michelson (Stanford) Co-Chair
Jay Norris (GSFC)
Mark Oreglia (U Chicago)
Jonathan Ormes (GSFC)
Geoff Pendleton (UAH)
Steve Ritz (GSFC)
Roger Romani (Stanford)
Jim Ryan (UNH)
Hartmut Sadrozinski (UCSC)
Dave Thompson (GSFC)
Trevor Weekes (Smithsonian - Hopkins)
Kent Wood (NRL)
Allen Zyrch (UC Riverside)

Science Working Group (SWG)

- **Scientific development of GLAST now led by SWG**
- **Representation from the Project, instrument teams, and community**
- **SWG:**

Project Scientist (Chair)
LAT PI
LAT US Team Reps (3)
LAT Foreign Team Reps (3)
GBM PI
GBM Foreign Team Rep (1)
Inter-disciplinary Scientists (4)

Ex-Officio
Program Scientist
Project Manager
Deputy Project Scientists (2)
DOE Representatives

Project SRD

- **SRD is new document based on AO SRD**
- **Key requirements of mission unchanged from AO SRD**
- **Requirements added for GBM instrument**
- **Project SRD signed and under configuration control**

Project SRD

Approved by:

Jonathan Ormes — 9/23/00
Jonathan Ormes
GLAST Project Scientist

Scott Lambros — 9/23/00
Scott Lambros
GLAST Project Manager

Peter Michelson — 9/23/00
Peter Michelson
LAT Principal Investigator

Charles Meegan — 9/23/00
Charles Meegan
GBM Principal Investigator

Project SRD

Reviewed by:

Guido Barbiellini
SWG, LAT Representative

Elliott Bloom
SWG, LAT Representative

Isabelle Grenier
SWG, LAT Representative

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SWG, LAT Representative

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Martin Pohl
SWG, IDS

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SWG, IDS

Neil Gehrels
GLAST Deputy Project Scientist

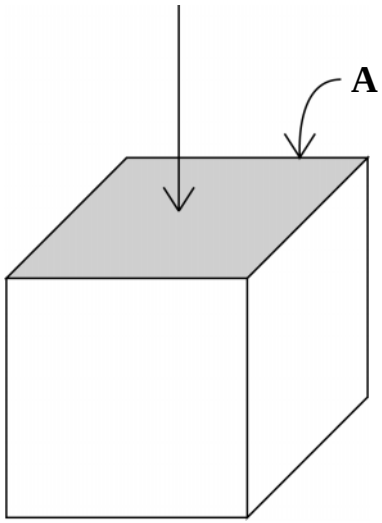
Steve Ritz
GLAST Deputy Project Scientist

Evaristo J. Valle
DOE LAT Project Manager

Definition of Terms

- **Effective Area:**

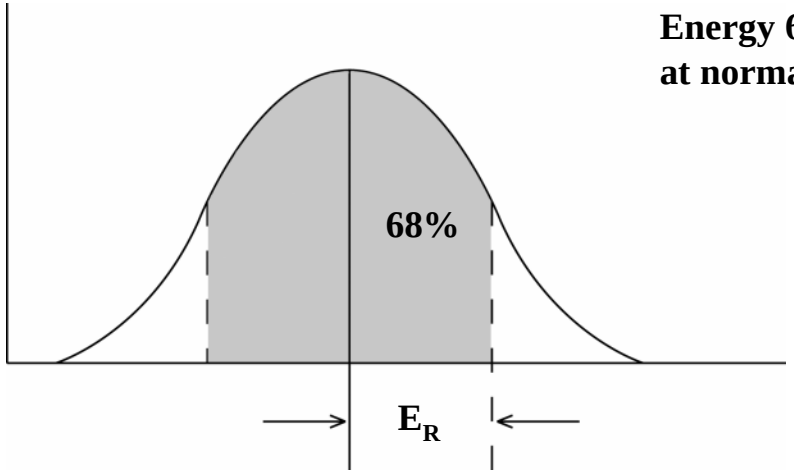
A_{eff}



Area at normal incidence times detection efficiency.

- **Energy Resolution:**

E_R

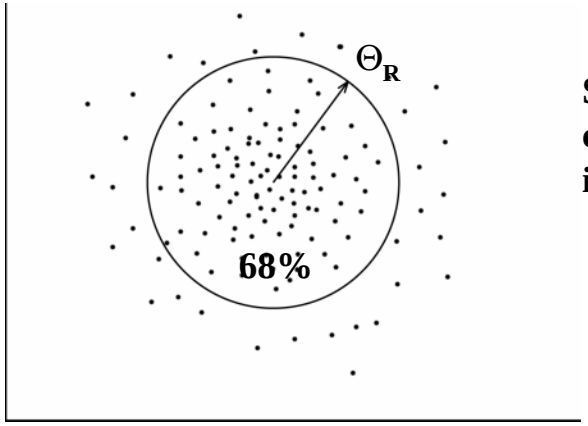


Energy 68% spread at normal incidence.

Definition of Terms

- **Angular Resolution:**

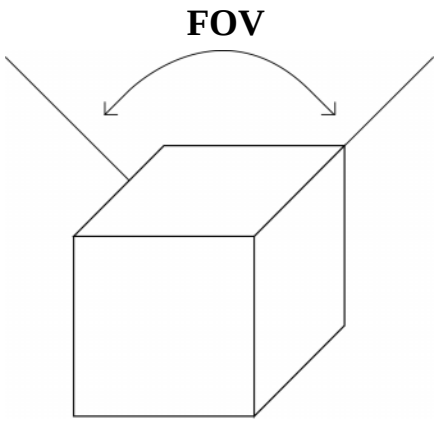
  Θ_R



Space angle for 68% containment at normal incidence.

- **Field of View:**

  FOV



Integral eff. area over solid angle Divided by peak eff. area.

- **Sensitivity:**

Flux of weakest source that can be detected at 5 sigma significance.

Summary of LAT Instrument Requirements

	Quantity	*EGRET*	*LAT Requirement* [1]	*LAT Goal* [1]	*LAT Minimum* [1]	*Science Topic*
1	**Energy Range Low Limit**	20 MeV	< 20 MeV	< 10 MeV	< 30 MeV	ALL
2	**Energy Range High Limit**	30 GeV	> 300 GeV	> 500 GeV	> 100 GeV	ALL
3	**Effective Area** [2]	1500 cm^2	> 8000 cm^2	> 12,000 cm^2	> 8000 cm^2	ALL
4	**Energy Resolution** [3] (on-axis, 100 MeV - 10 GeV)	10%	< 10%	< 8%	< 20%	ALL
5	**Energy Resolution** [3] (on-axis, 10-300 GeV)		<20%	<15%	<30%	ALL
6	**Energy Resolution** (>60° incidence, >10 GeV) [4]		< 6%	< 3%	NA [5]	Dark Matter

Summary of LAT Instrument Requirements

	Quantity	*EGRET*	*LAT Requirement* [1]	*LAT Goal* [1]	*LAT Minimum* [1]	*Science Topic*
7	**Single Photon Angular Resolution - 68%** [6] (on-axis, E>10 GeV)	0.5°	< 0.15°	< 0.1°	< 0.3°	ALL
8	**Single Photon Angular Resolution - 68%** [6] (on-axis, E=100 MeV)	5.8°	< 3.5°	< 3°	< 5°	ALL
9	**Single Photon Angular Resolution - 95%** [6] (on-axis)		< 3 x $\theta_{68\%}$	< 2 x $\theta_{68\%}$	< 4 x $\theta_{68\%}$	ALL
10	**Single Photon Angular Resolution** (off axis at 55°)		< 1.7 times on-axis	< 1.5 times on-axis	< 2 times on-axis	ALL
11	**Field of View** [7]	0.5 sr	> 2 sr	> 3 sr	> 1.5 sr	ALL
12	**Source Location Determination** [8,9]	5 arcmin	< 0.5 arcmin	< 0.3 arcmin	< 1 arcmin	UGOs , GRBs

Summary of LAT Instrument Requirements

	Quantity	*EGRET*	*LAT Requirement* [1]	*LAT Goal* [1]	*LAT Minimum* [1]	*Science Topic*
13	**Point Source Sensitivity** [9,10] (> 100 MeV)	~1 x 10^{-7} cm^{-2} s^{-1}	< 6 x 10^{-9} cm^{-2} s^{-1}	< 3 x 10^{-9} cm^{-2} s^{-1}	< 8 x 10^{-9} cm^{-2} s^{-1}	AGN, UGOs, Pulsars, GRBs
14	**Instrument Time Accuracy** [11]	0.1 ms	< 10 µsec	< 2 µsec	< 30 µsec	Pulsars, GRBs
15	**Background Rejection**[12] (Contamination of high latitude diffuse sample in any decade of energy for >100 MeV.)	<1%	<10%	<1%	<15%	Diffuse
16	**Dead Time**	100 ms /event	< 100 µs /event	< 20 µs /event	< 200 µs /event	GRBs
17	**GRB Location Accuracy On-Board** [13]		< 10 arcmin	< 3 arcmin	NA [5]	GRBs
18	**GRB Notification Time To Spacecraft** [14]		< 5 sec	< 2 sec	NA [5]	GRBs

Summary of GBM Instrument Requirements

	Quantity	*BATSE*	*GBM Requirement* [1]	*GBM Goal* [1]	*GBM Minimum* [1]	*Science Topic*
19	**Energy Range Low Limit**	25 keV	< 10 keV	< 5 keV	< 20 keV	ALL
20	**Energy Range High Limit**	10 MeV	> 25 MeV	> 30 MeV	> 20 MeV	ALL
21	**Field of View** [2]	4π	> 8 sr	> 10 sr	> 6 sr	ALL
22	**Energy Resolution** [3] (0.1 - 1.0 MeV)		< 10%	< 7%	< 12%	GRBs
23	**GRB Alert Location** [5]		NA [4]	< 15 deg	NA [4]	GRBs

Summary of GBM Instrument Requirements

	Quantity	*BATSE*	*GBM Requirement* [1]	*GBM Goal* [1]	*GBM Minimum* [1]	*Science Topic*
24	**GRB Notification Time To Spacecraft** [6]		< 2 sec	< 1 sec	< 5 sec	GRBs
25	**Dead Time Average**		< 10 μsec/event	< 3 μsec/event	< 50 μsec/event	GRBs
26	**Instrument Time Accuracy** [7]	10 μsec	< 10 μsec	< 2 μsec	< 30 μsec	GRBs
27	**Burst Sensitivity** [8]	0.2 cm^{-2} s^{-1}	< 0.5 cm^{-2} s^{-1}	< 0.3 cm^{-2} s^{-1}	< 1.0 cm^{-2} s^{-1}	GRBs

Science Requirements on the GLAST Mission

	Quantity	*GLAST Requirement* [1]	*GLAST Goal* [1]	*GLAST Minimum* [1]	*Science Topic*
28	**Mission Lifetime** (<20% degradation) [2]	> 5 years	> 10 years	> 3 years	ALL
29	**Telemetry Downlink Orbit Average**	> 300 kbps	> 1 Mbps	> 300 kbps	ALL
30	**Telemetry Downlink Realtime** [3]	> 1 kbps	> 2 kbps	> 0.5 kbps	GRBs
31	**Telemetry Uplink Realtime** [3]	> 1 kbps	> 2 kbps	> 0.5 kbps	GRBs, AGN
32	**Time to Respond to TOO's on Ground** [4]	< 6 hours	< 4 hours	< 12 hours	GRBs, AGN
33	**Spacecraft Repointing Times for Autonomous Slews** [5]	< 10 min	< 5 min	NA	GRBs, AGN

Science Requirements on the GLAST Mission

	Quantity	*GLAST Requirement* [1]	*GLAST Goal* [1]	*GLAST Minimum* [1]	*Science Topic*
34	**GRB Notification Time to Ground by Spacecraft** [6]	< 7 sec	< 4 sec	< 10 sec	GRBs, AGN
35	**Pointing Accuracy Absolute** [7]	< 2^{o}	< 0.5^{o}	< 5^{o}	ALL
36	**Pointing Knowledge** [7]	< 10 arcsec	< 5 arcsec	< 20 arcsec	ALL
37	**Observing Modes**	- Rocking zenith pointing - Pointed mode [8]			ALL
38	**Targeting**	No restrictions on pointing of axis normal to LAT			ALL
39	**Uniformity of Sky Coverage during Scanning** [9]	< ± 20%	< ± 10%	< ± 30%	ALL

Science Requirements on the GLAST Mission

	Quantity	*GLAST Requirement* [1]	*GLAST Goal* [1]	*GLAST Minimum* [1]	*Science Topic*
40	**Observatory Absolute Time Accuracy** [10]	< 10 μsec	< 3 μsec	< 30 μsec	Pulsars
41	**Observatory Absolute Position Accuracy**	< 3.3 km	< 1 km	< 10 km	Pulsars
42	**Observing Efficiency** [11]	> 90 %	> 95%	> 80%	ALL
43	**Data Loss** [12]	< 2 %	< 1%	< 5%	ALL
44	**Data Corruption** [13]	$< 10^{-10}$	$< 3 \times 10^{-11}$	$< 3 \times 10^{-10}$	ALL

LAT Instrument Requirements: Footnotes

1 Requirement = value to design to; Goal = value to strive for to enhance science; Minimum = value that if not satisfied triggers a Project review.

2 Maximum (as function of energy) effective area at normal incidence. Includes inefficiencies necessary to achieve required background rejection. Effective area peak is typically in the 1 to 10 GeV range.

3 Equivalent Gaussian 1 sigma, on-axis.

4 Effective area for side incidence is 0/1 to 0.2 that of normal incidence for high resolution measurements.

5 NA = Not Applicable. Minimum values are not applicable for parameters that were not Requirements in the AO 99-OSS-03 Announcement of Opportunity.

6 Space angle.

7 Integral of effective area over solid angle divided by peak effective area. Geometric factor is Field of View times Effective Area.

8 High latitude source of 10^{-7} cm^{-2} s^{-1} flux at >100 MeV with a photon spectral index of -2.0 above a flat background and assuming no spectral cut-off to 10 GeV. 1 sigma radius. 1-year survey.

9 Derived quantities delimited by double-lined box.

10 Sensitivity at high latitudes after a 1-year survey for a 5 sigma detection.

11 Relative to spacecraft time.

12 Assuming a high-latitude diffuse flux of 1.5×10^{-5} cm^{-2} s^{-1} sr^{-1} (>100 MeV) assuming a photon spectral index of -2.1 with no spectral cut-off.

13 For burst (>20 sec duration) with > 100 photons above 1 GeV. This corresponds to a burst of ~5 photons cm^{-2} s^{-1} peak rate in the 50 - 300 keV band assuming a spectrum of broken power law at 200 keV from photon index of -0.9 to -2.0. Such bursts are expected to occur in the LAT FOV ~10 times per year.

14 Time relative to onset of GRB.

GBM Instrument Requirements: Footnotes

1 Requirement = value to design to; Goal = value to strive for to enhance science; Minimum = value that if not satisfied triggers a Project review.

2 Integral of effective area over solid angle divided by peak effective area. Geometric factor is Field of View times Effective Area. Should overlap with LAT FOV.

3 Equivalent Gaussian. 1 sigma. On axis.

4 NA= Not Applicable. The addition of the GRB monitor was a "goal" in the AO 99-OSS-03. The broad-band spectroscopic capability of the GRB instrument is upgraded here to be a requirement. The location of the bursts is listed only as a goal.

5 1 sigma radius. For burst of brightness 10.0 cm^{-2} s^{-1} in 50 - 300 keV band and a duration of 1 second or longer.

6 Time relative to a GBM GRB trigger. Used for both 'rapid ground notification' or 'burst alert' through TDRSS (or equivalent real-time link) and for 'LAT notification'.

7 Relative to spacecraft time.

8 GRB peak brightness sensitivity, 50 - 300 keV range 5 sigma detection.

Science Requirements: Footnotes

1 Requirement = value to design to; Goal = value to strive for to enhance science; Minimum = value that if not satisfied triggers a Project review..

2 20% degradation = no more than 20% loss of LAT science return.

3 Uplink telemetry rate for at least 80% of time outside of SAA.

4 Response time for the MOC to uplink a spacecraft repointing after the decision is made to respond to a Target of Opportunity (TOO).

5 Time for 70° slew.

6 Time from spacecraft receipt of GRB notification from GBM or LAT to delivery to the Gamma-ray Coordinates Network (GCN) computer for 80% of all GRBs detected by the GBM or LAT.

7 1 sigma radius.

8 Pointing of axis normal to LAT to within 30° of source. (No science constraint on roll axis.)

9 Sky coverage exposure uniformity integrating for 7 days, not including SAA effects.

10 Relative to Universal Time, 1 sigma r.m.s.

11 Fraction of time with data return, not including SAA effects.

12 Fraction of data taken by the instruments but not delivered to the IOC. Not including SAA data loss. Not including instrument deadtime.

13 Fraction of undetected corrupted events.